

HR-164 A Computerized Method for the Hydrologic Design of Culverts

Key Words: Culverts, Watershed, Streamflow, Computerized design

ABSTRACT

A comprehensive computer program has been developed which includes both current and new innovative design procedures for the design of high-way culverts. One major factor has come to light in this study. Use of the program clearly shows that the hydrologic portion of the design has a greater influence on the selection of the final culvert size than the hydraulic analysis of the culvert. For instance, reasonable use of the available storage can permit a greater reduction in culvert size than can be obtained by neglecting storage effects but selecting the most efficient culvert inlet shape. The entire hydrologic sequence has been included in the program and is tailored to fit each individual site. A second important conclusion reached is that only a very small temporary storage volume at the culvert site (equivalent to one to two tenths of an inch over the watershed) will permit using a smaller size culvert. This essentially means that detailed hydrologic study of all sites should be considered in culvert design. Also, the results show that each culvert site is unique and should be investigated on its own merits using the pro-posed computerized design method.

Use of the program also has shown that the mathematical equations developed in the study to estimate rainfall amounts for various storm durations and recurrence intervals are within the range of accuracy of published values contained in USWB-TP-40. In addition, the equation developed to represent the design curve of the ISHC Peak Rates of Runoff chart is acceptable as a peak discharge predictor. Results also have shown that the rainfall- runoff relationship devised by the SCS adequately describes the "losses" of rainfall due to interception, infiltration, and depression storage.

Another important finding was the effect of storm duration on the results obtained. Several methods in current utilize standard storm durations (3 hr, 6 hr, 24 hr, and/or 10 day) for all watershed sizes. This study has shown that much shorter duration storms should be used on the smaller watersheds. In addition, several durations should be analyzed at each site because of runoff volume effects (rather than peak rates) on headwater depths when storage effects delay outflow from the system. Seven storm durations were selected for application in the hydrologic model. Since temporary storage immediately upstream of the culvert site is used in the computerized design method, the volume of runoff becomes as important as the peak discharge. Longer duration storms result in greater volumes of runoff which in turn usually result in increased headwater depths. However, the rate of increase in headwater depth decreases as the storm duration increases. Thus the maximum headwater depth tends to level off or stabilize as storm duration continues to increase.

The sensitivity of headwater depth to other parameters was also investigated. The two most important parameters were culvert size and the amount of storage available at the site. Lesser effects were caused

by a change in the SCS curve number for determining runoff amounts. An increase in recurrence interval logically caused an increase in headwater depth (as rainfall and runoff amounts increase), but the amount of increase was more dependent on the other parameters. The efficiency of the culvert inlet had only a negligible effect on headwater depth for pipe culverts and a minor effect for box culverts. The time distribution of rainfall used had a large effect on peak inflow rate but a lesser effect on headwater depth, dependent again on the other parameters. Storage tended to smooth out the peak discharge variations.

Loss of storage volume due to sedimentation over a period of years results in increased headwater depths. At sites which have only small volumes available, the increase is minor. However, at sites which have large storage volumes available, the increase can become important enough to influence the final size of culvert used at the site. In these cases, the storage volumes input to the program should be arbitrarily reduced at the time of design to determine the effect that a reduction in storage volume will have on headwater depth.

The results confirm the hydrologic routing concepts stating that the outflow discharge is less than the maximum inflow discharge. As this reduced discharge flows downstream, the next downstream structure may also be somewhat reduced in size, depending on additional inflows and use of ponding at the downstream sites. Also, inflow to the site under consideration might also be reduced due to existing structures upstream. This possibility deserves investigation to ascertain if it could be added to the proposed design method.